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Non-Linear Acoustics for Non-Destructive Testing



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Development Team Leader
Q-6 Detonation Science and
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Managed by Triad National Security, LLC for the U.S. Department of Energy's NNSA

Work developed in LANL's Geophysics group with contributions from:

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- TJ Ulrich now in LANL's Detonation Science and Technology group
- Jim Ten Cate, now retired
- Marcel Remillieux, still in the Geophysics group
- Lukasz Pieczonka, AGH University of Science and Technology, Krakow, Poland
- Cedric Payan, Université Aix-Marseille, Laboratoire de Mécanique et d'Acoustique CNRS UMR-7031, France

Outline

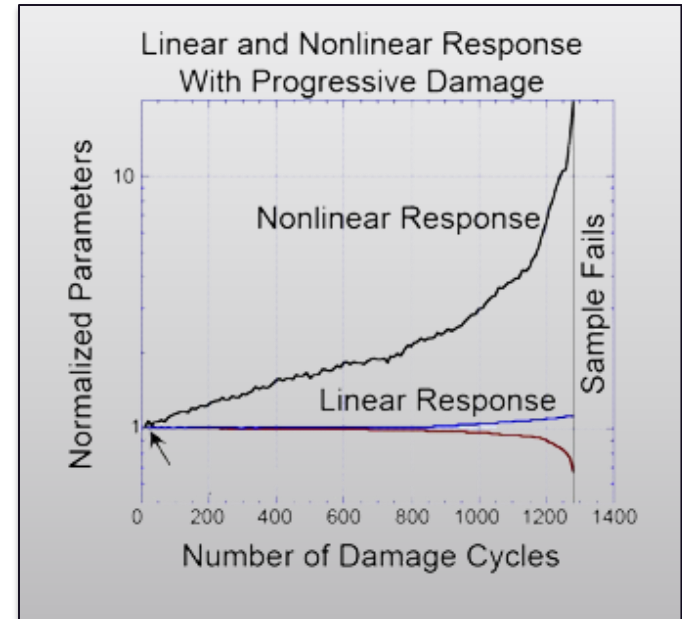
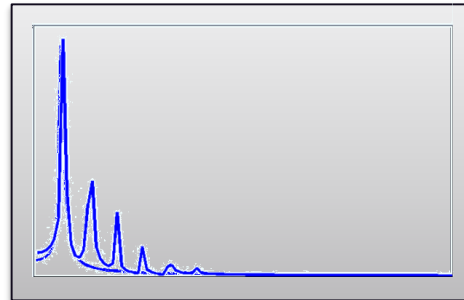
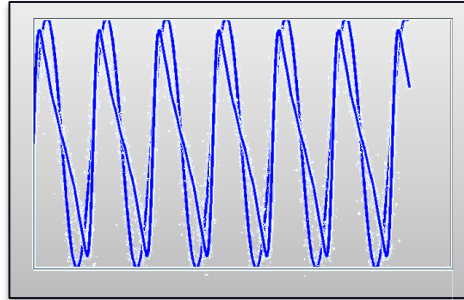


- Acoustics and NDT
- Nonlinear Acoustics
- Time Reversal
- 3-Component Excitation
- Non Contact Excitation
- More Applications
 - Composite Materials
 - Metallic Samples
 - Concrete Evaluation
 - Geophysics

Acoustics and Non Destructive Testing

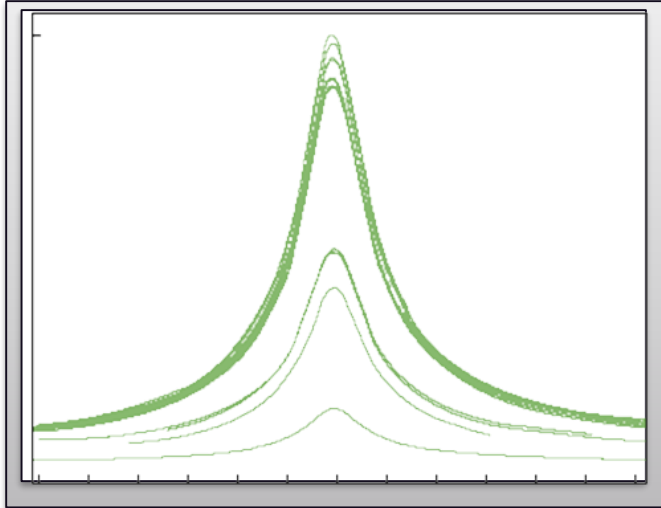


Nonlinear acoustics

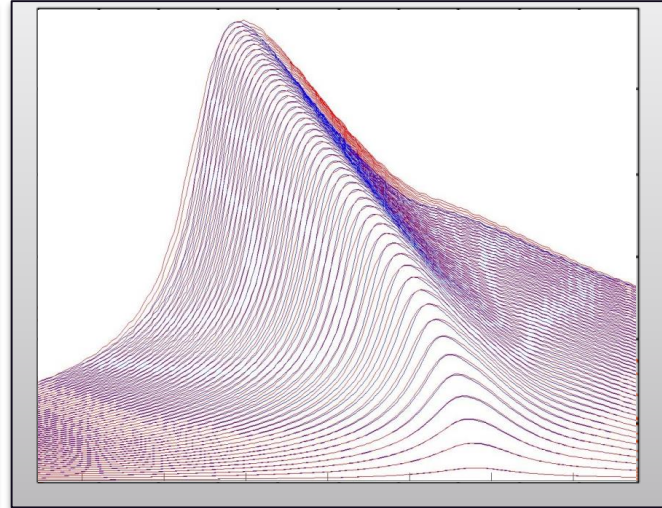


Nonlinear Signatures

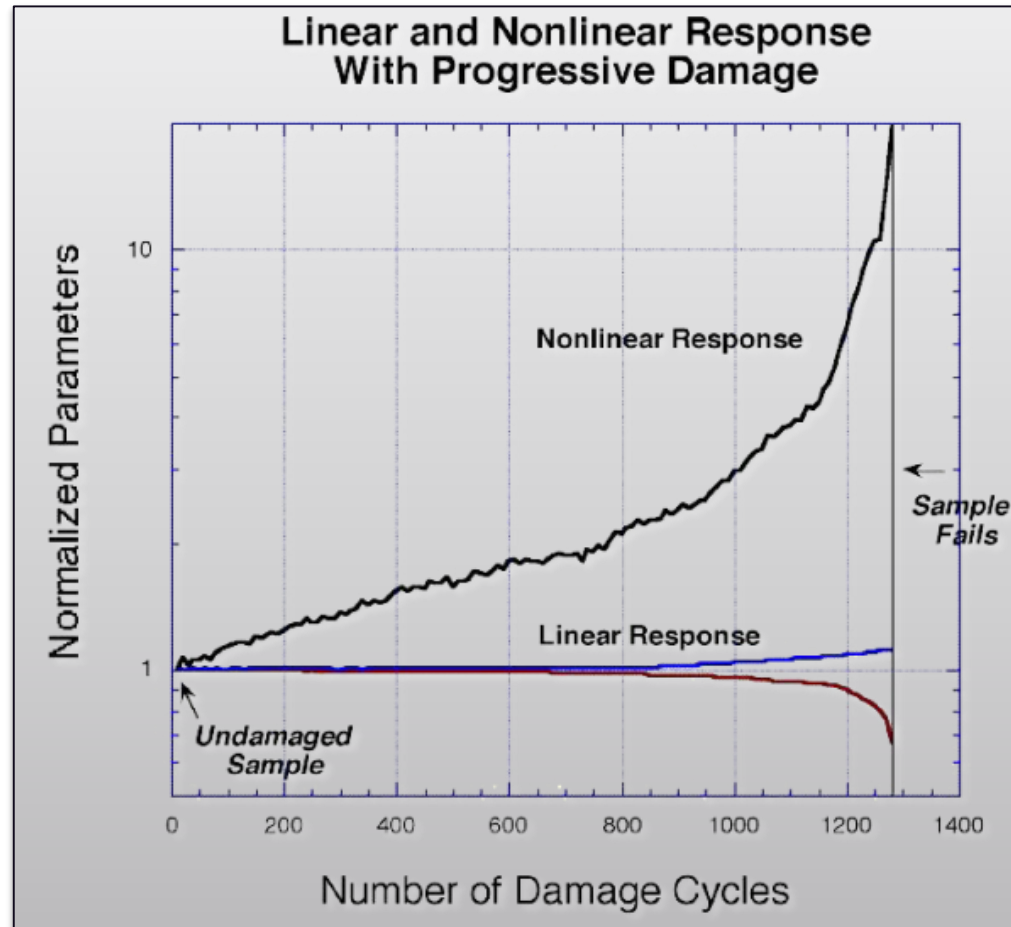
**Linear
(undamaged)**



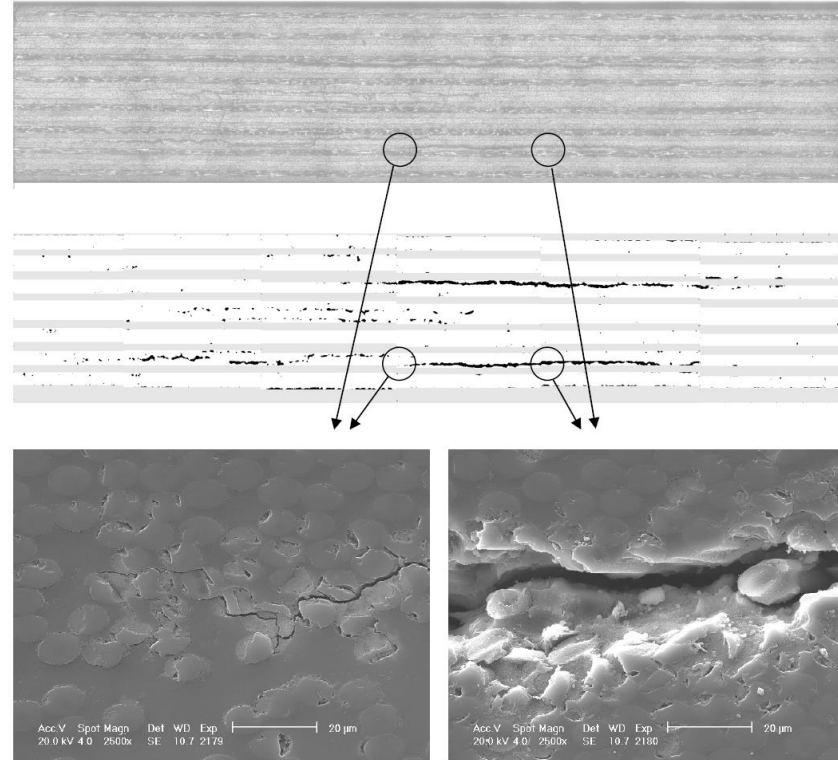
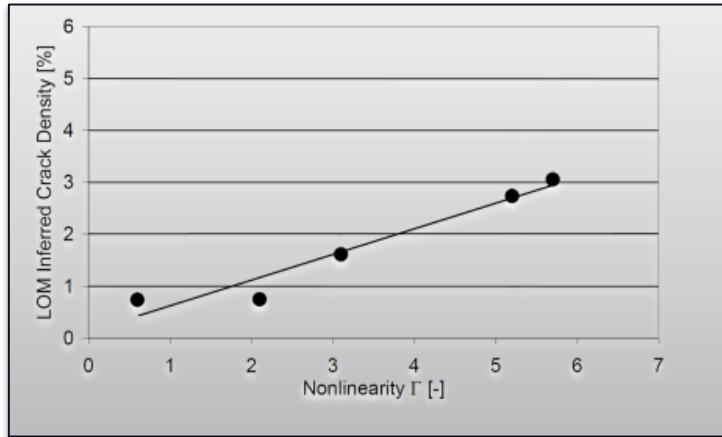
**Nonlinear
(damaged)**



Nonlinearity as a measure of fatigue damage

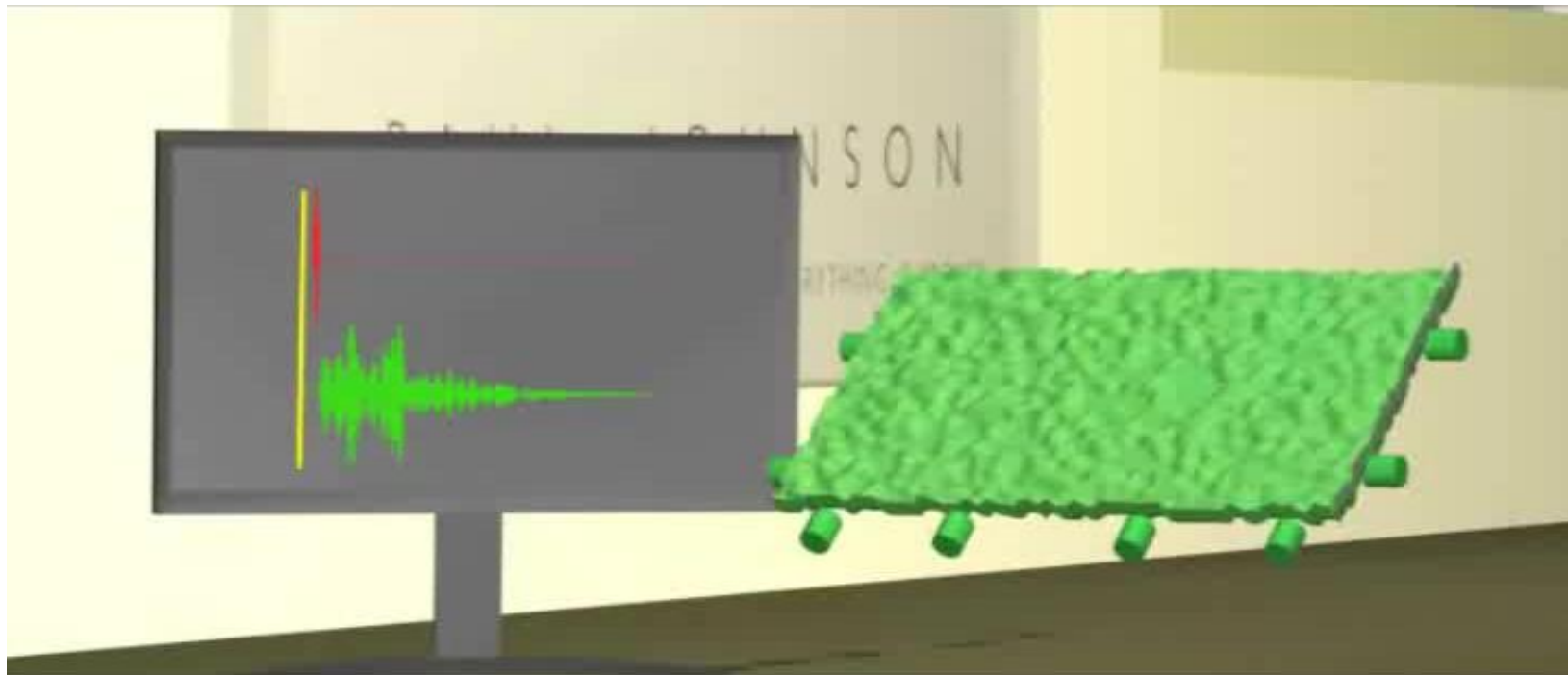


Correlation between damage and nonlinear parameter



Time Reversal

Time Reversal

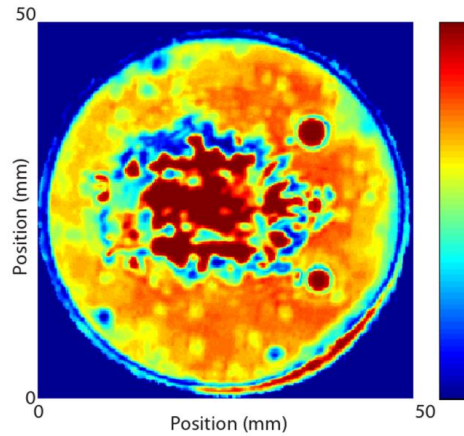




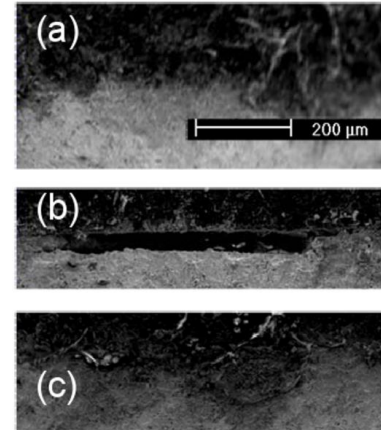
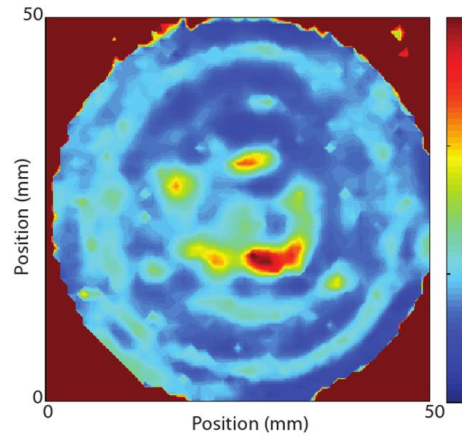
Interface Delamination



Linear

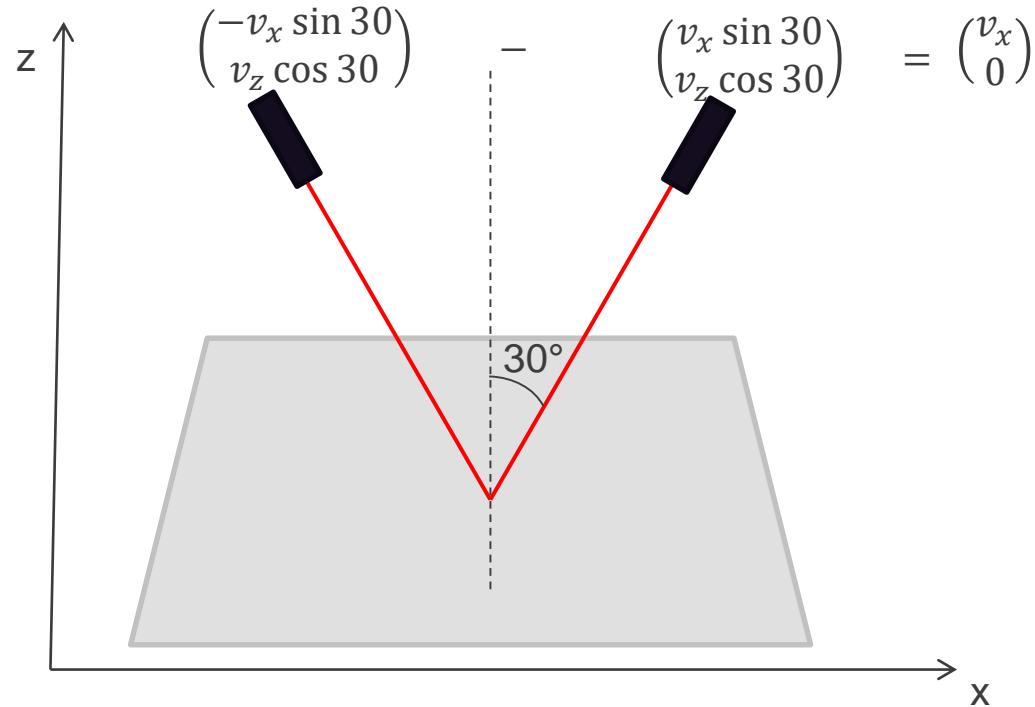


Non Linear

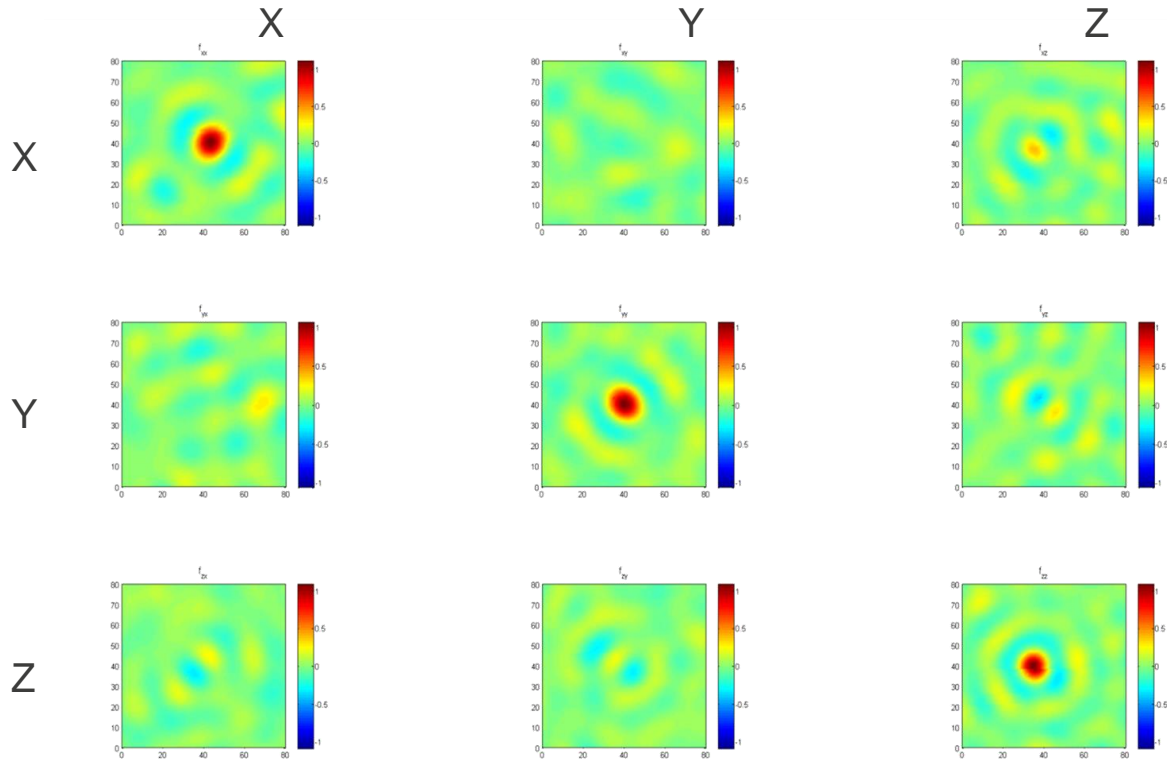


3-Component Excitation

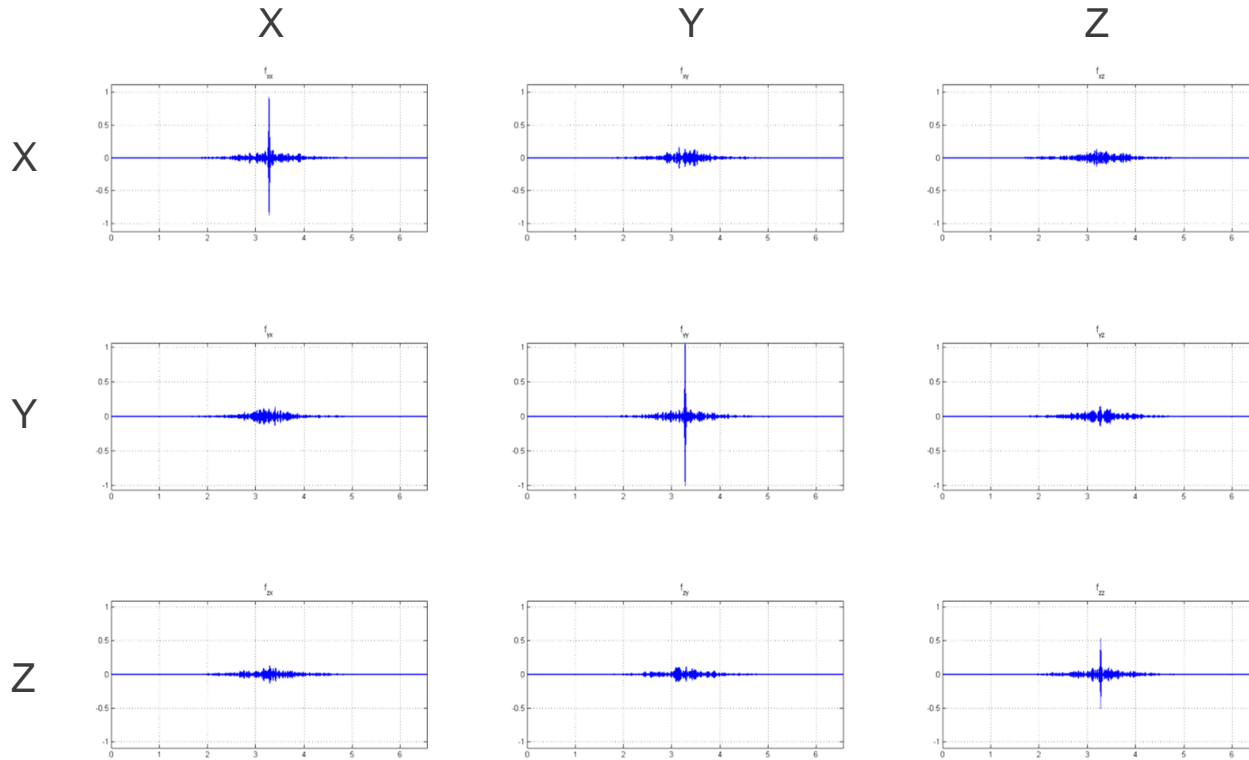
Measuring In-Plane components



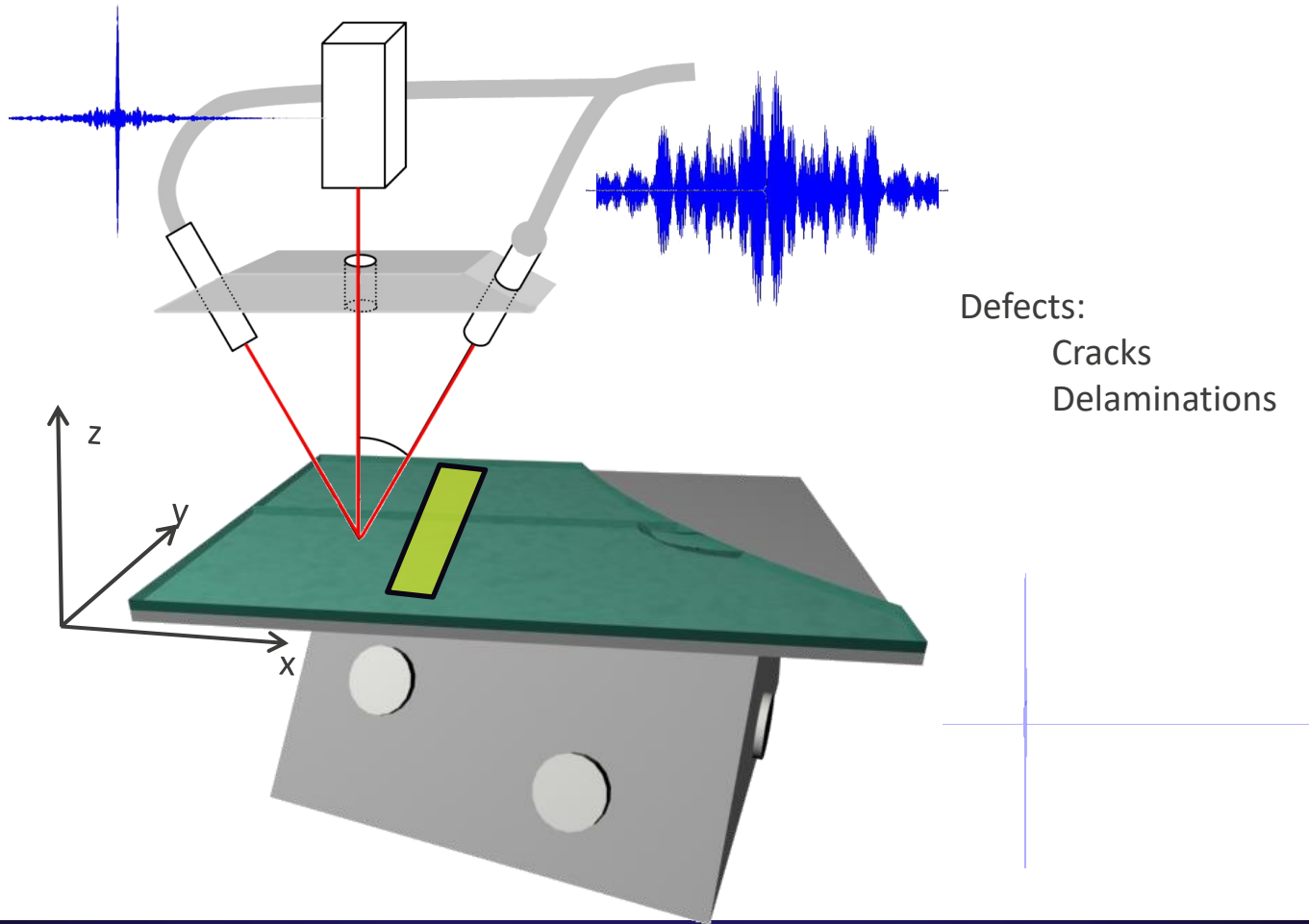
Selected component focus



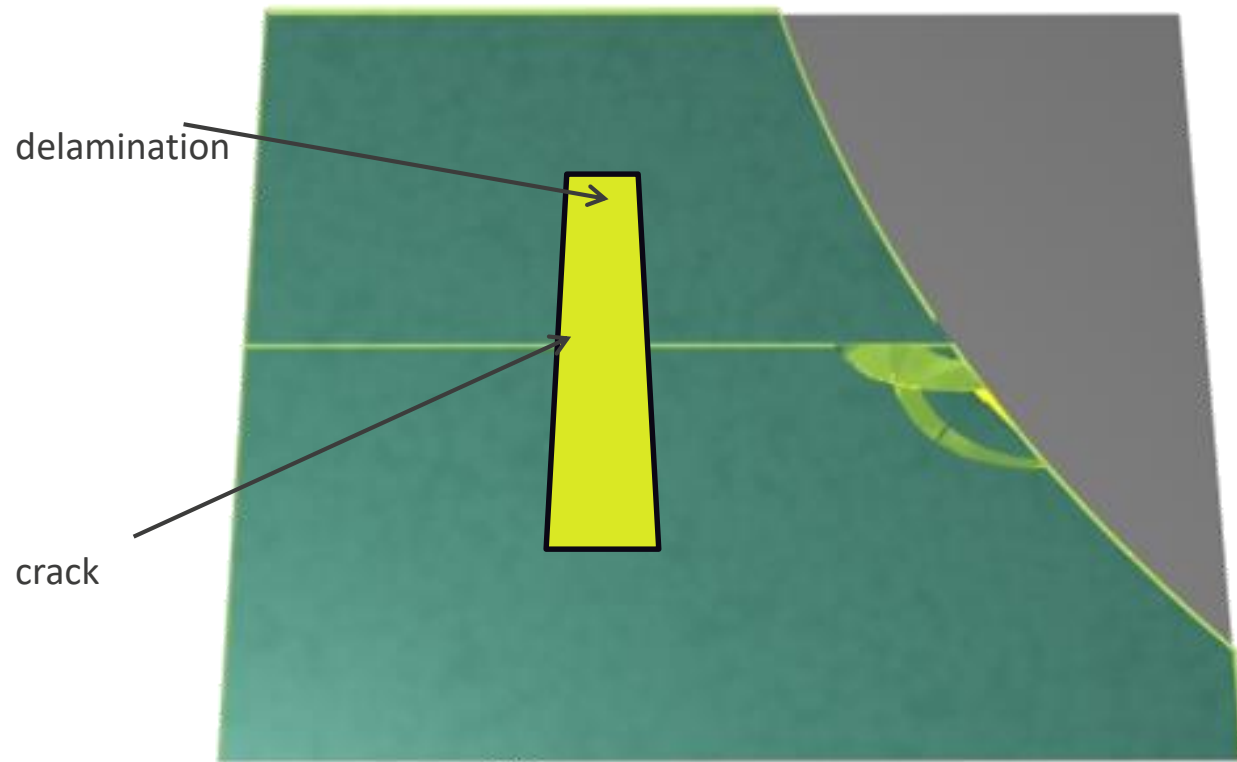
Selected component focus



Setup and sample

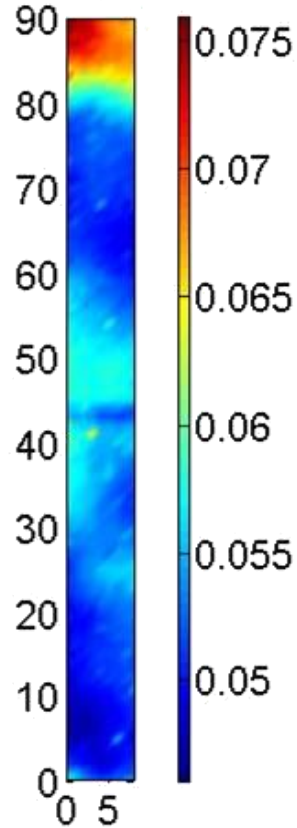


Scan area

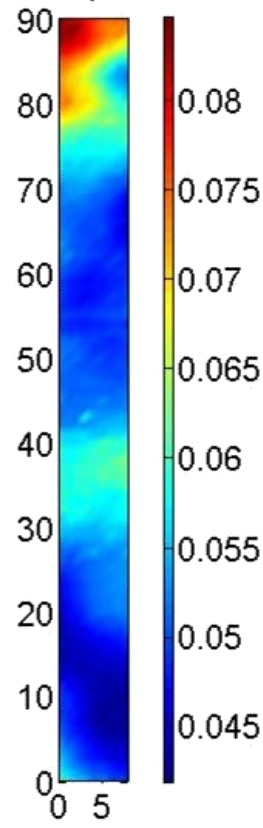


Linear image 75kHz

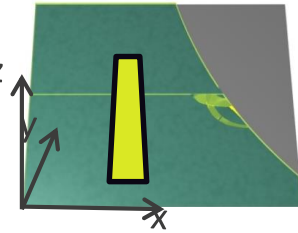
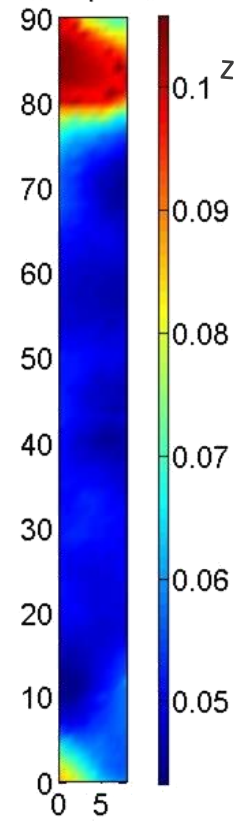
X component



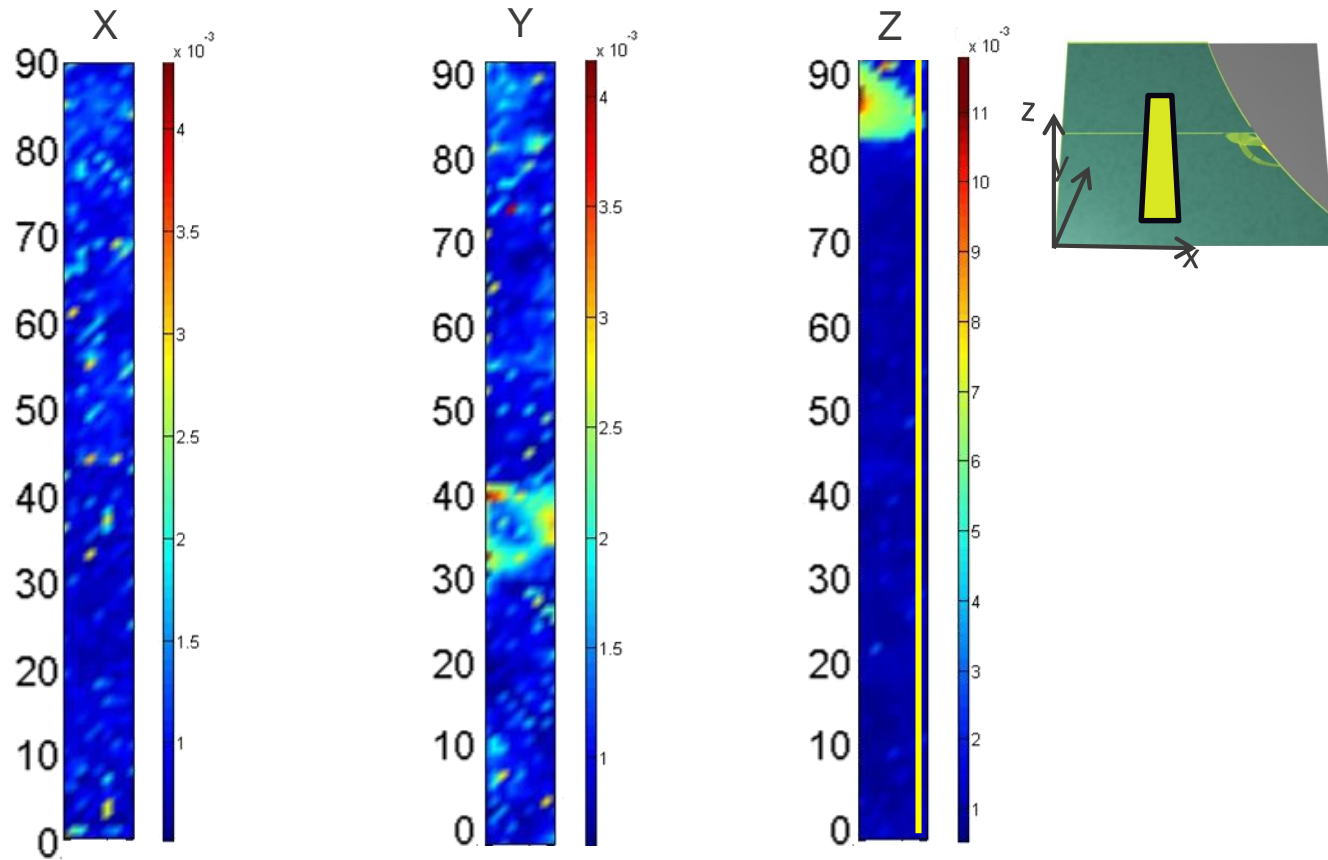
Y component



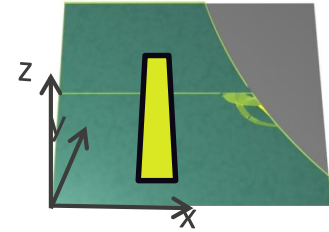
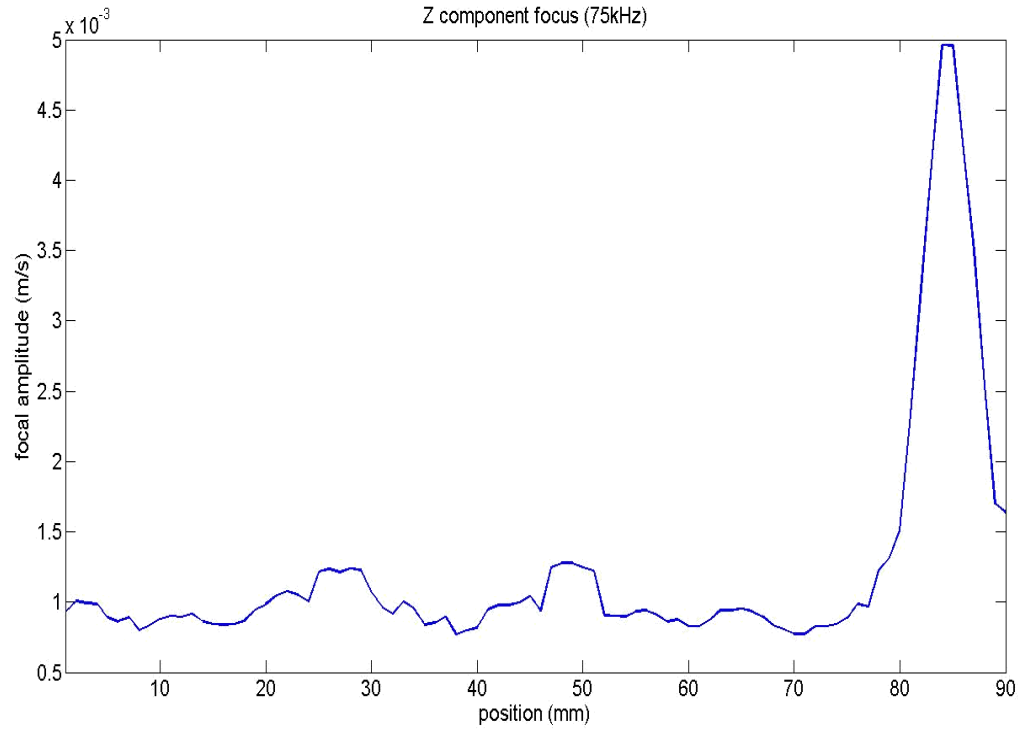
Z component



Nonlinear image 75kHz

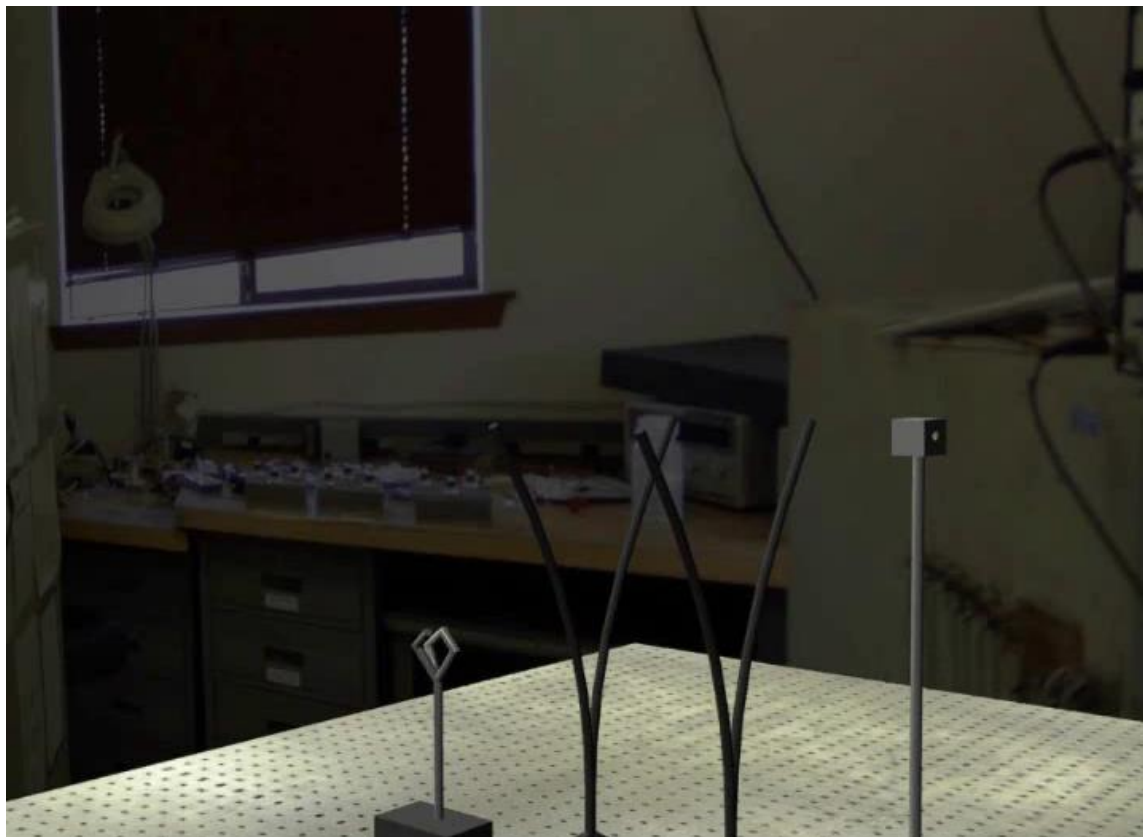


Nonlinear image 75kHz

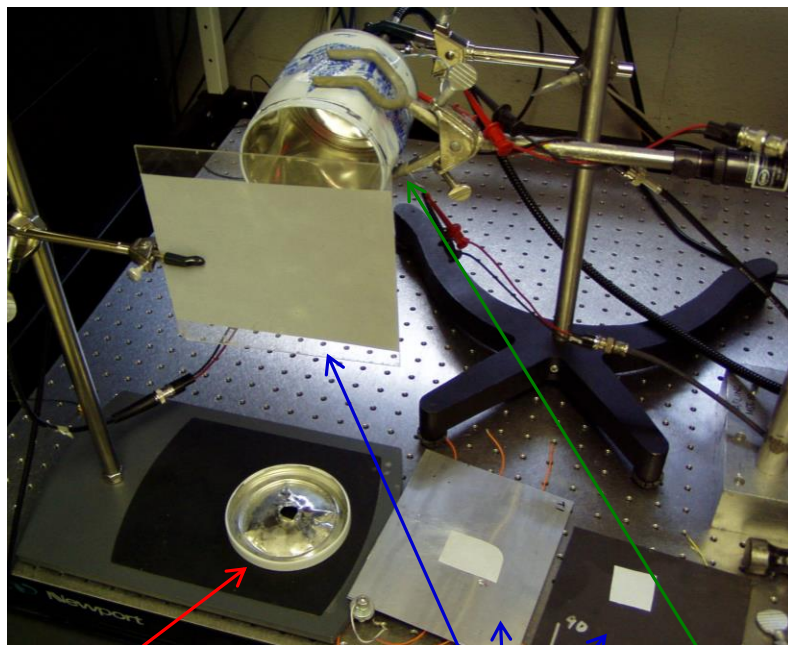


Non-Contact Excitation

Noncontact Source



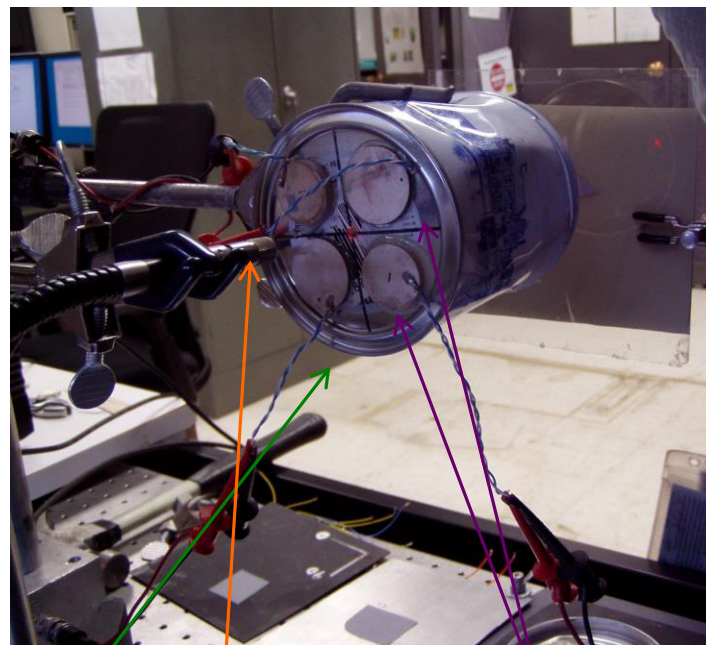
Prototype Candy Can ... or TRANS



Lid

Test Plates

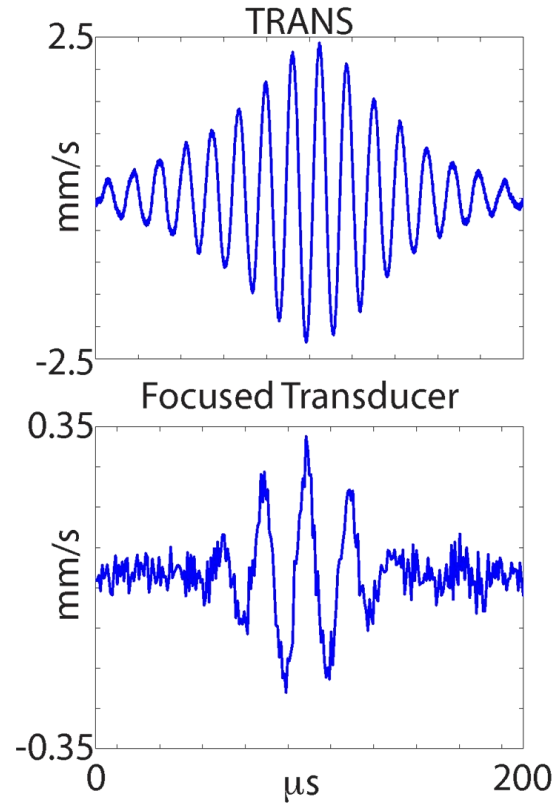
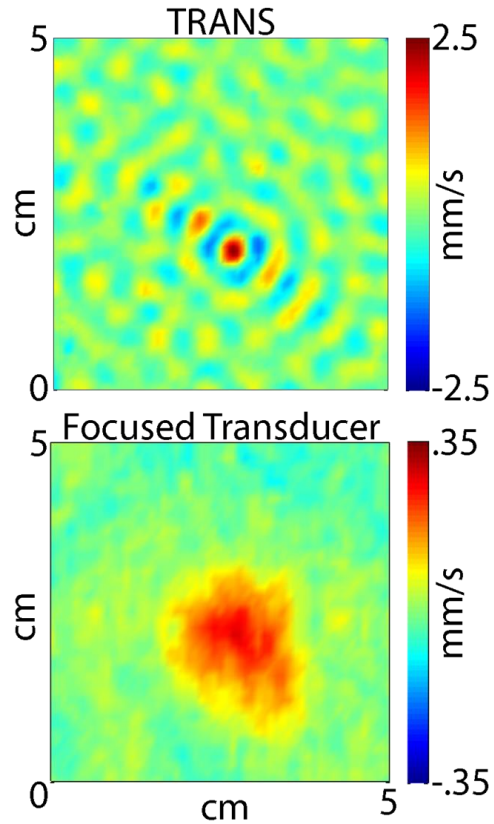
Cavity



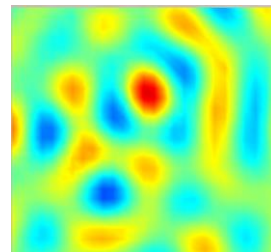
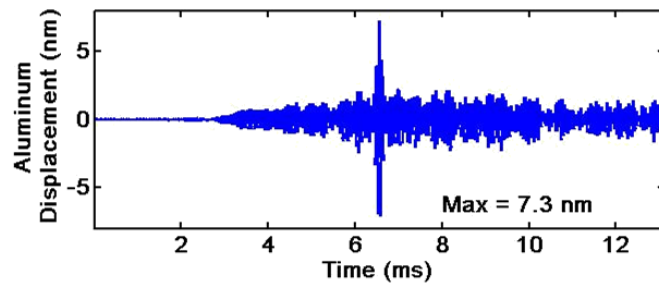
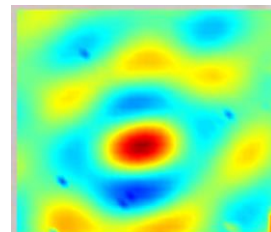
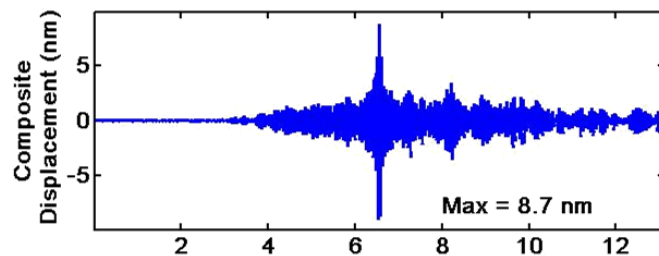
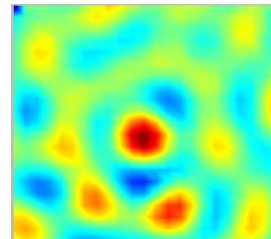
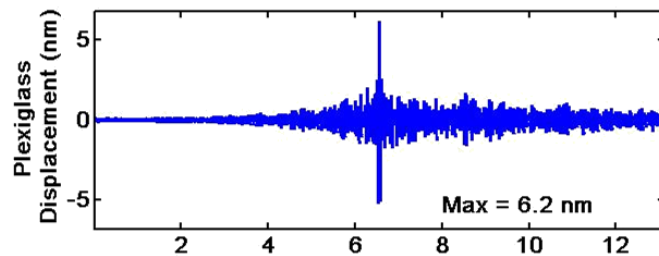
Fiber-optic LV

Transducers

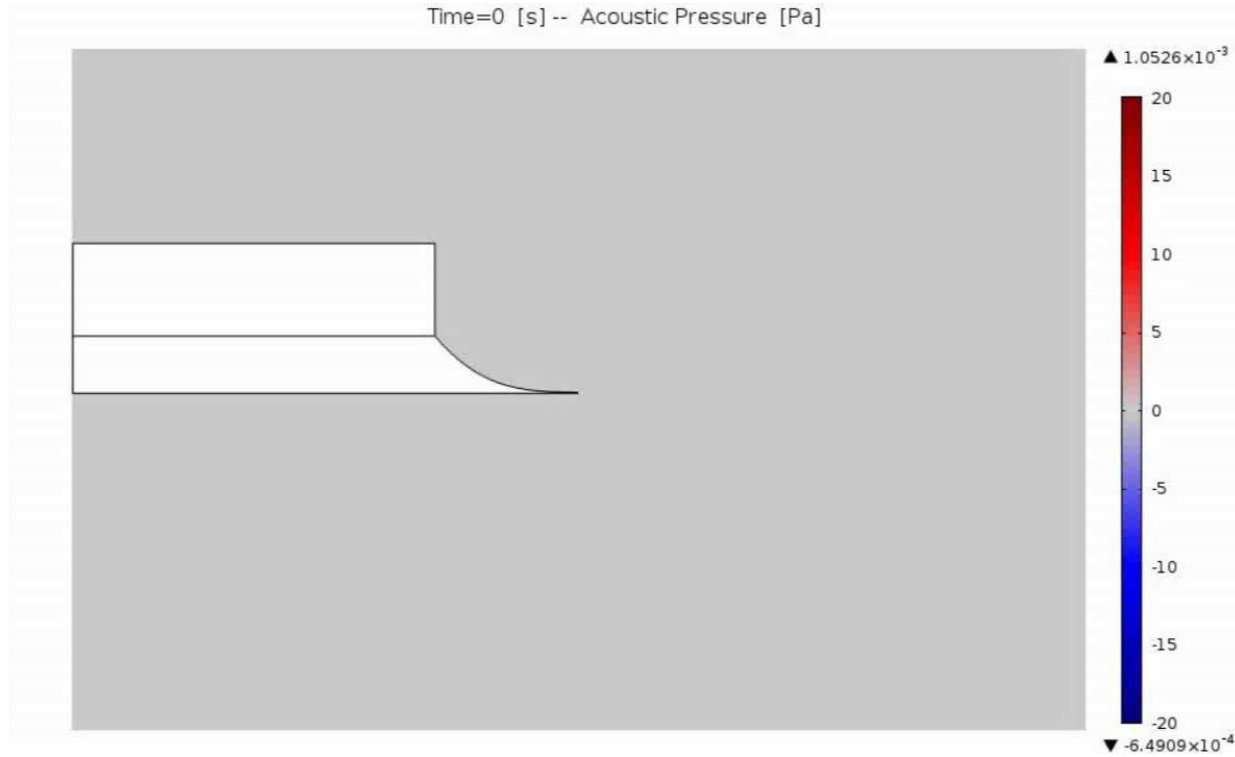
Head to Head: TRANS vs. FUT



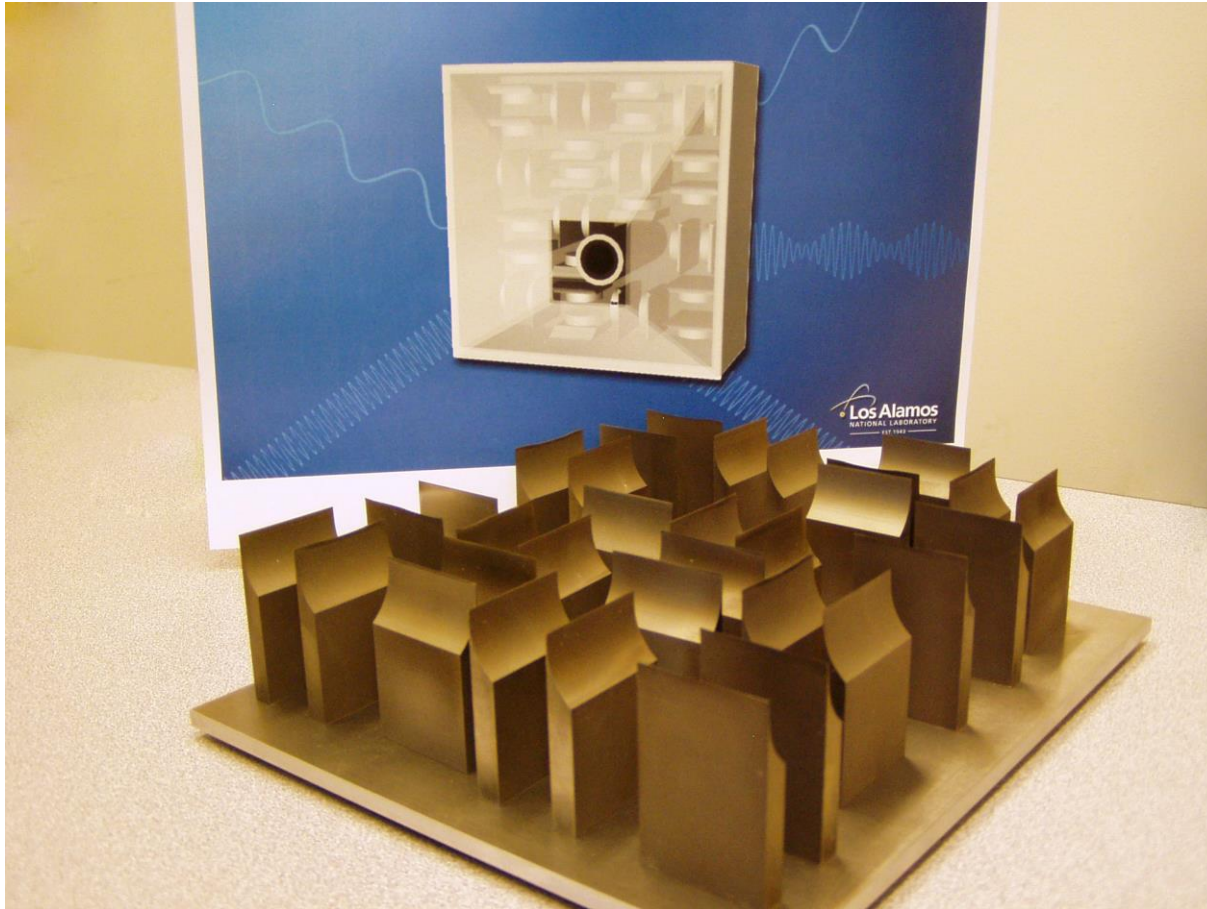
Application to different materials



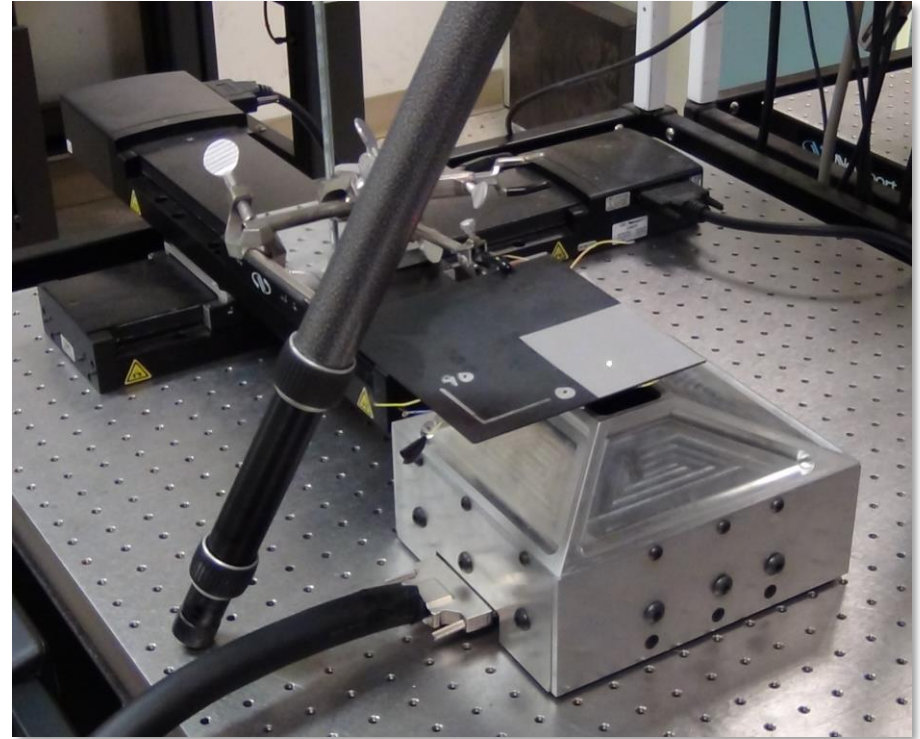
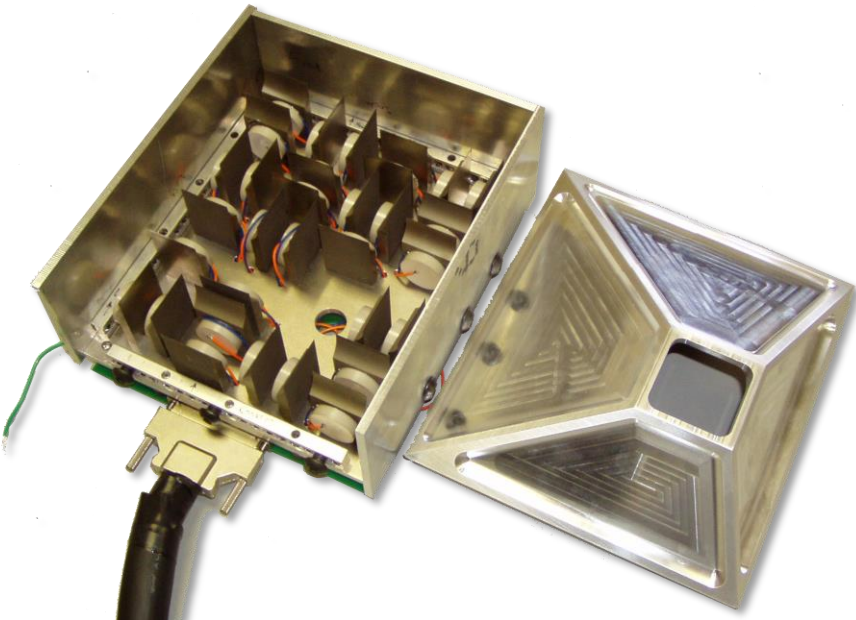
PZT/Air Coupling



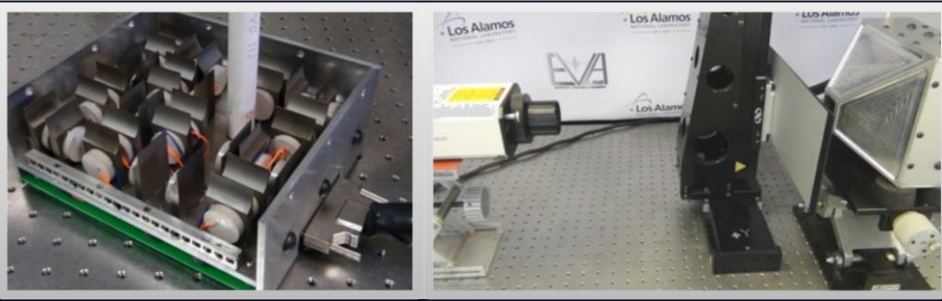
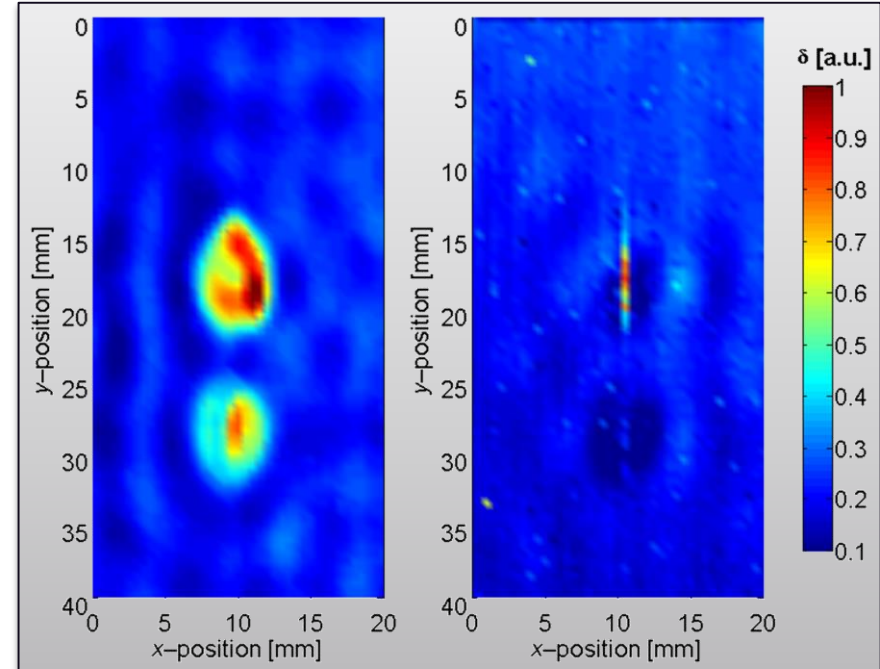
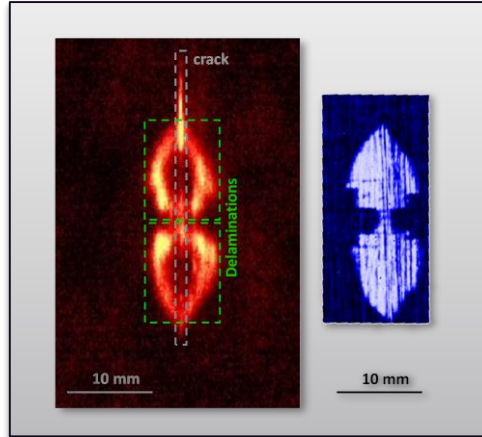
Final Design



Final Design

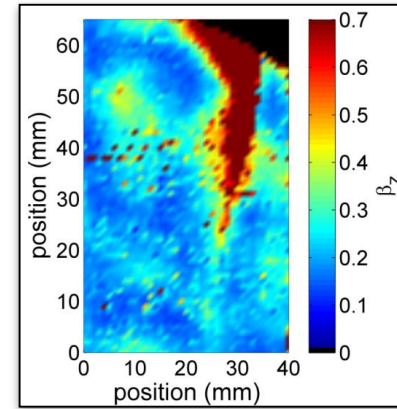
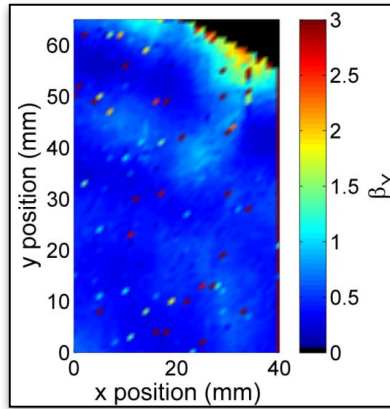
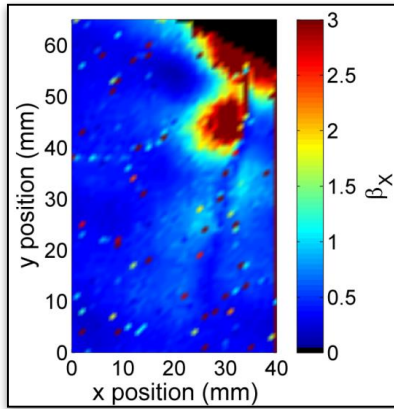
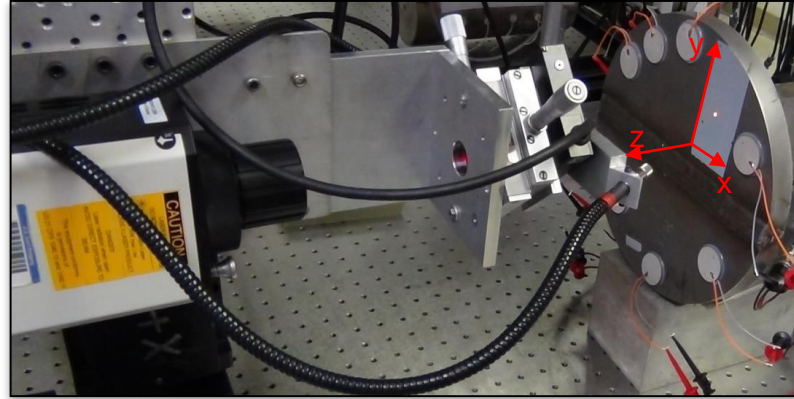
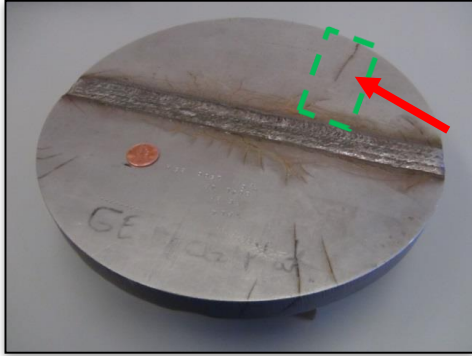


Non contact crack characterization

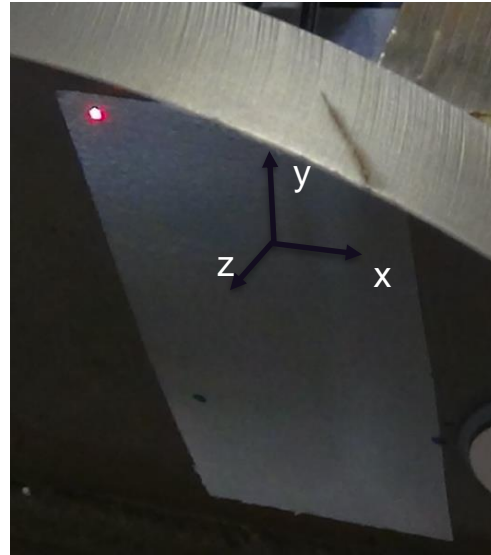


Other Applications

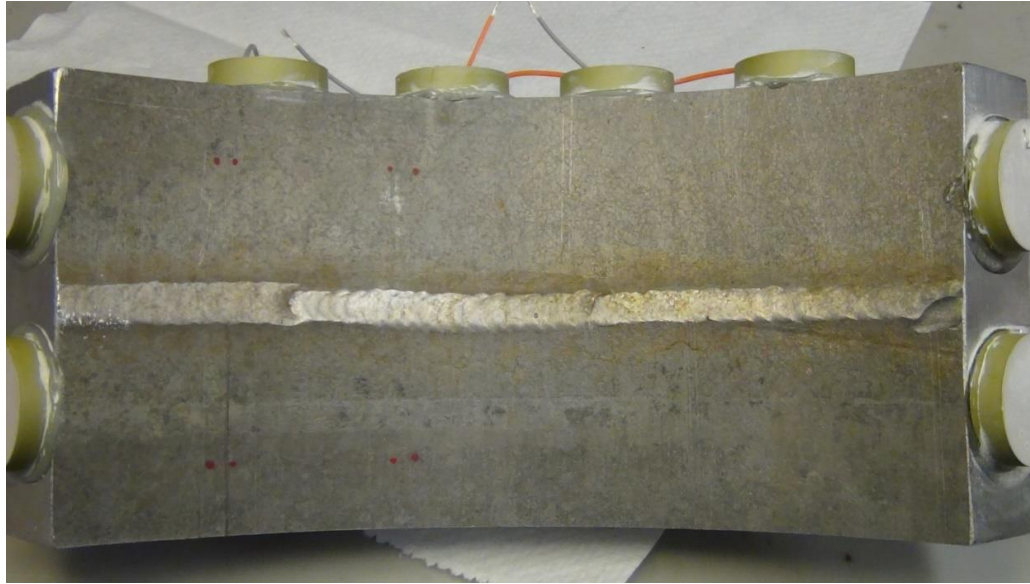
Stress Corrosion Cracking



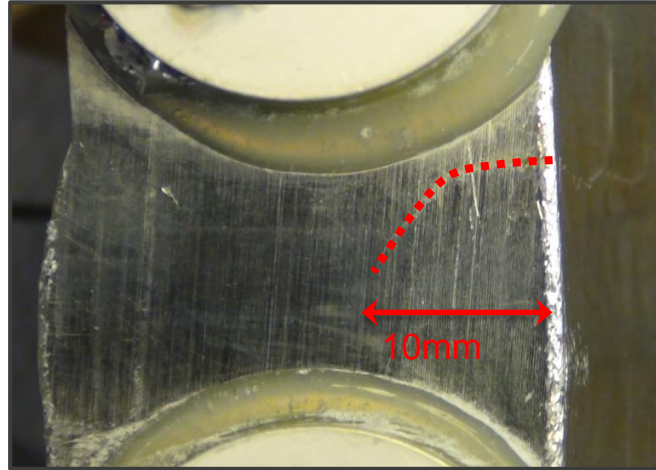
Stress corrosion cracking



Stress corrosion cracking



Stress corrosion cracking



Focal spot depths:
@100kHz = 9.75 mm
@200kHz = 4.87 mm

Stress corrosion cracking

Image @ 200kHz
2nd harmonic

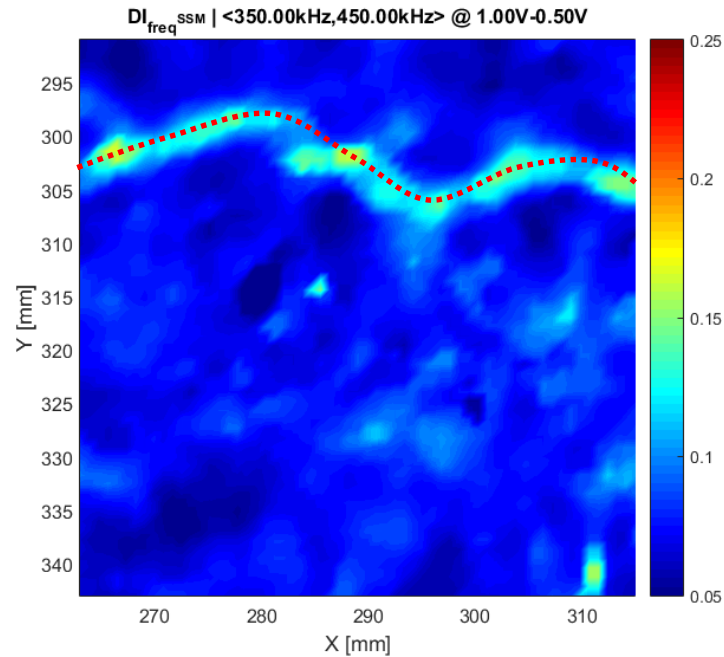
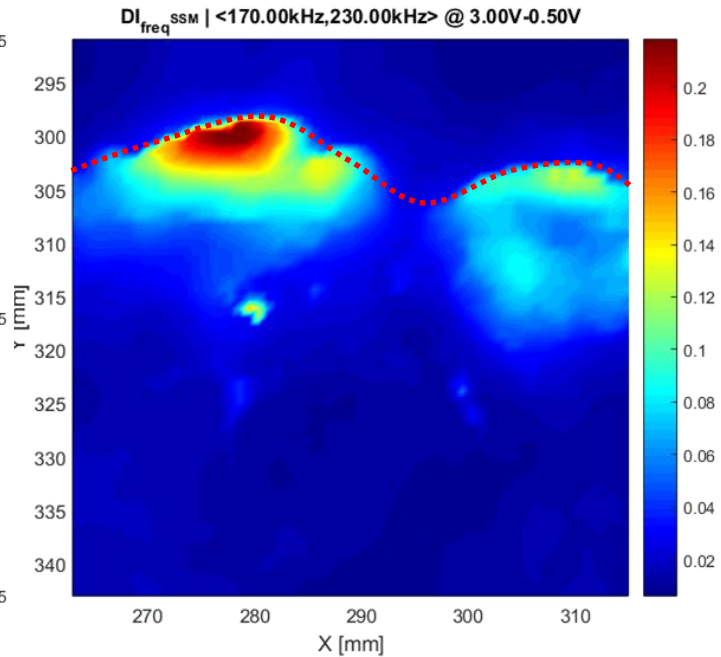
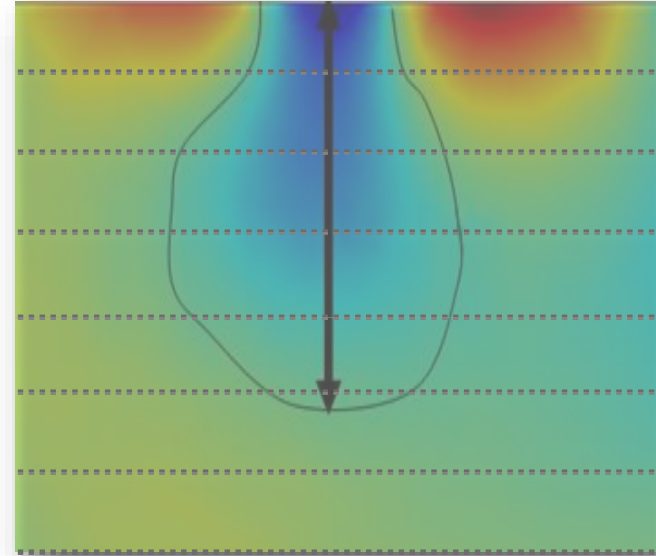


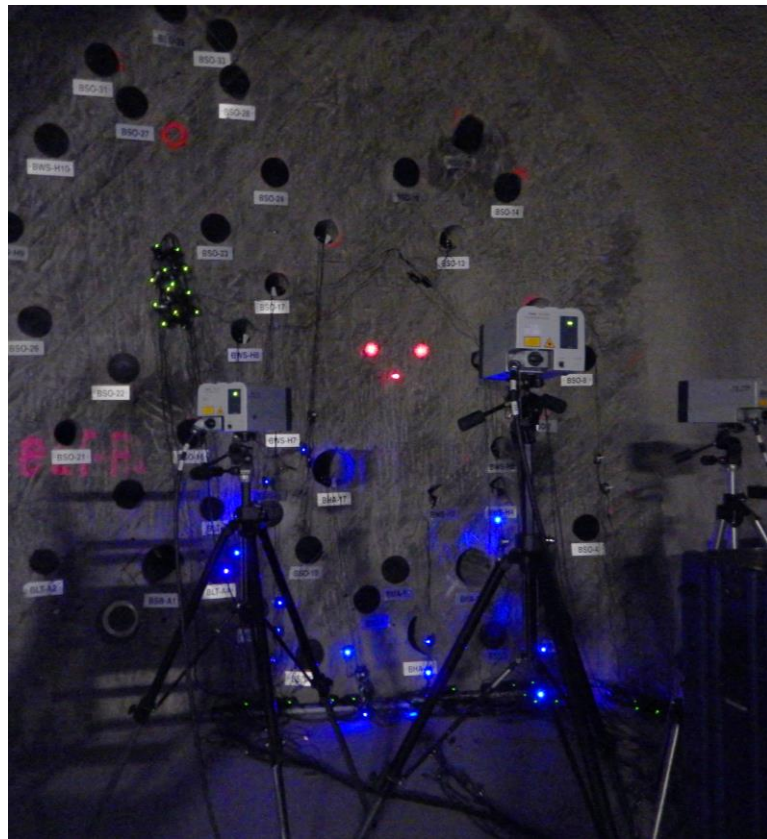
Image @ 100kHz
2nd harmonic



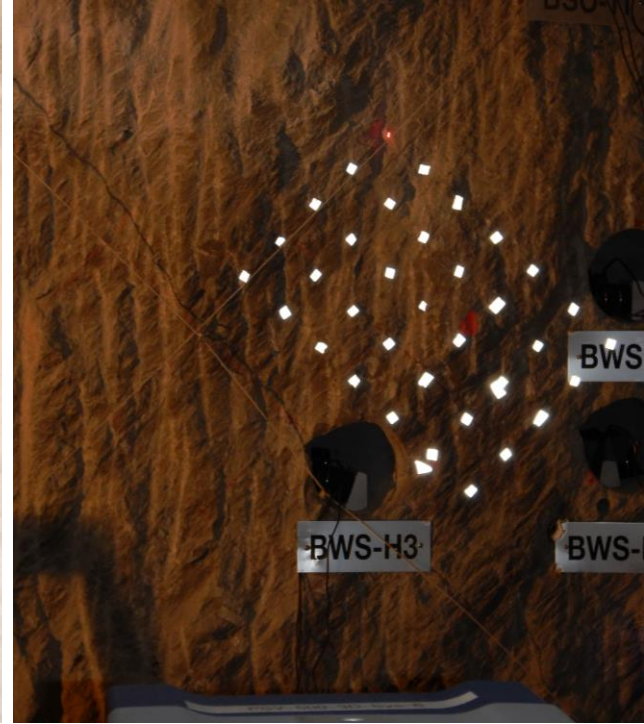
Concrete damage characterization



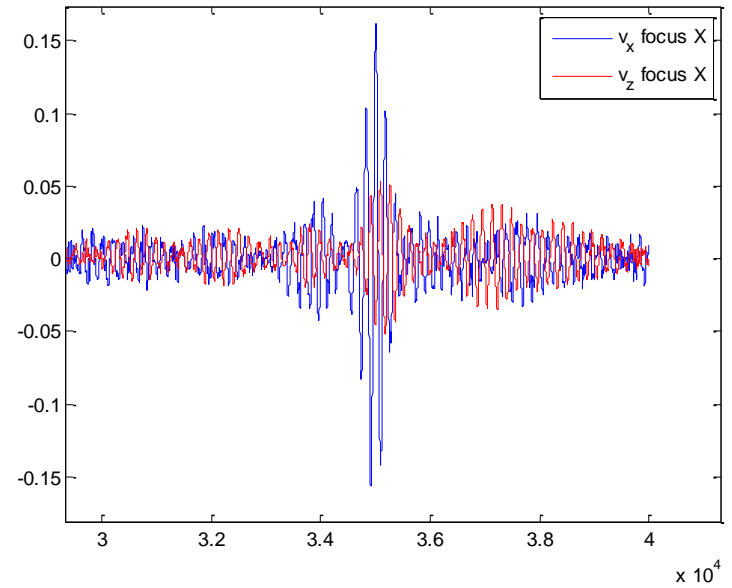
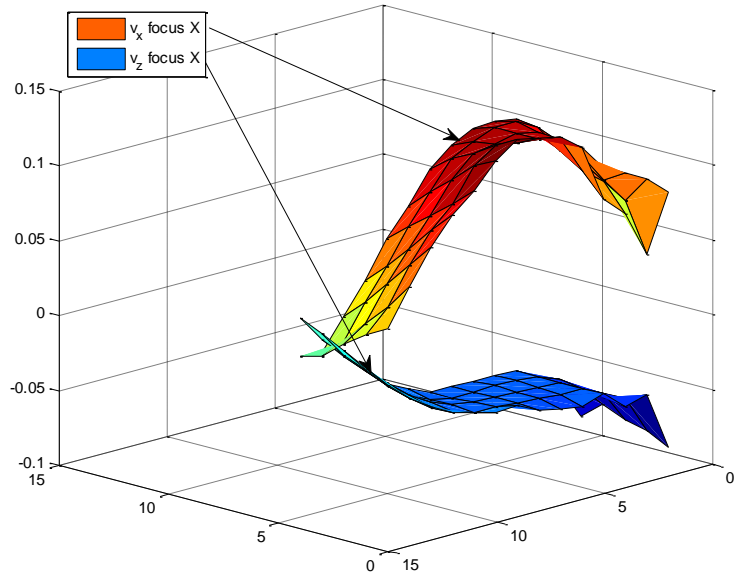
Mont Terri



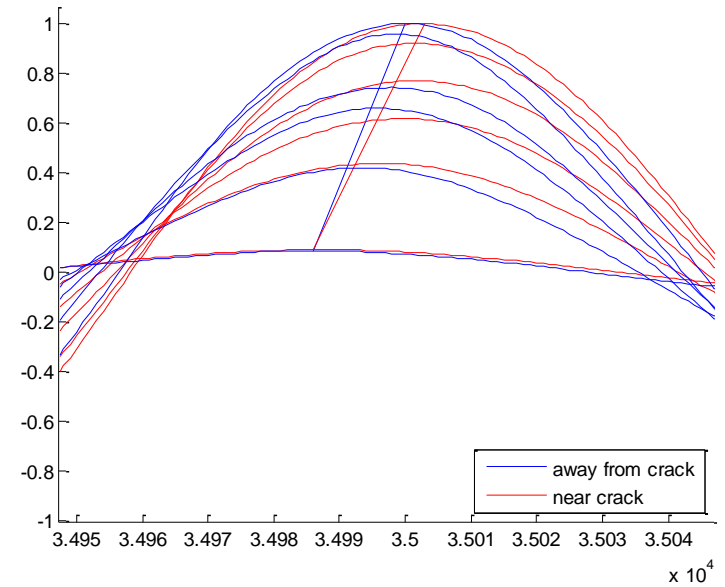
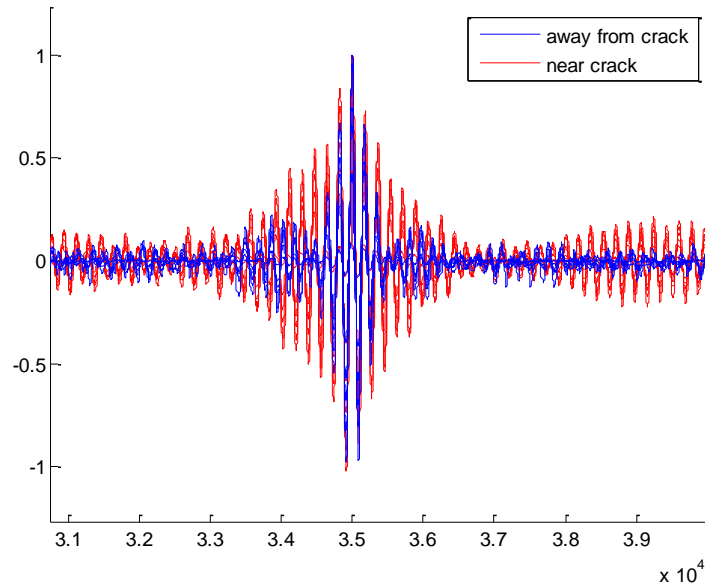
Setup



Results: Focus



Results: Nonlinear Signature



Conclusion

- Nonlinear acoustics and time reversal is a powerful combination for NDE
- This work continues in LANL's Geophysics group
- The Detonation Science and Technology group is looking into adapting those techniques to RF waves and for granular material characterization